

THIN FILM TRANSISTOR, LIQUID CRYSTAL DISPLAY PANEL, AND
METHOD OF MANUFACTURING THIN FILM TRANSISTOR

Background of the Invention

Technical Field

5 The present invention relates to a thin film transistor
used for an active-matrix-type liquid-crystal display and
a method for fabricating the thin film transistor, and a
liquid-crystal display panel using the thin film
10 transistor.

Prior Art

15 An active-matrix-type liquid-crystal display unit using a
thin film transistor realizes displaying by arranging
gate electrodes (Y-electrodes) and data electrodes (X-
electrodes) like a matrix, injecting liquid crystal
between a TFT array substrate configured by arranging
thin film transistors (TFTs) at intersections of the
matrix and a substrate facing and superimposed above the
20 TFT array substrate, controlling a voltage to be applied
to the liquid crystal by the thin film transistors, and
using the electro-optical effect of the liquid crystal.

25 In this case, a normal-stagger-type (top-gate-type)
structure and a reverse-stagger-type (bottom-gate-type)
structure are known as structures of a thin film
transistor. Figure 7 shows a typical structure of a
normal-stagger-type (top-gate-type) thin film transistor.
As shown in Figure 7, the top-gate-type thin film
30 transistor is configured by forming an opaque film 102 on
an insulating substrate 101 such as a glass substrate and
providing an insulating film 103 made of silicon oxide
SiO_x, silicon nitride SiN_x or the like on the opaque film

102. Moreover, a drain electrode 104 and a source
electrode 105 which are respectively configured of an ITO
(indium-tin oxide) film are provided on the insulting
film 103 by keeping a channel interval, an amorphous-
5 silicon film (a-Si-film) 106 for covering the electrodes
104 and 105 is provided, a gate insulating film 107 made
of SiOx, SiNx or the like is provided on the film 106,
and a gate electrode 108 is provided on the film 107, and
thereby an island-shaped region referred to as a-Si
10 island is formed.

As a process for fabricating the thin film transistor,
there is the so-called 7PEP (PEP: Photo Engraving
Process) structure. In case of the 7PEP structure, the
15 drain electrode 104 and source electrode 105 respectively
made of an ITO film are patterned and then, the a-Si film
106 is formed through the CVD (Chemical Vapor Deposition)
art and patterned like an island. Thereafter, the gate
insulating film 107 is formed through the CVD art and
20 patterned into a predetermined shape. Thereafter, a TFT
is completed by forming, for example, an aluminum (Al)
film as the gate electrode 108 through sputtering and by
patterning the film.

25 However, because the number of steps increases in case of
the 7PEP structure, a next-generation 4PEP structure
requiring a less number of steps is proposed. The 4PEP
structure is configured by etching the gate insulating
film 107 and a-Si film 106 below the gate electrode 108
30 at the same time. That is, the gate electrode 108, gate
insulating film 107, and a-Si film 106 are continuously
etched through one-time patterning process by using a

gate-electrode plating pattern as a mask. Therefore, the 4PEP structure is very superior in reduction of the number of manufacturing steps.

5 Though not concerned with reduction of the number of manufacturing steps, there is the official gazette of Japanesse Published Unexamined Patent Application No. 1-68968 as a background art relating to an electrode structure of the present invention. This official
10 gazette discloses a thin film transistor art of arranging a source electrode and a drain electrode in parallel with each other and moreover making these electrodes orthogonal to a gate electrode.

15 Moreover, a display data signal and a scanning signal are supplied to a drain line and a gate line connected with a thin film transistor from an external unit. In general, a gate line is connected to a gate electrode on an insulating film made of SiOx or SiNx provided on an
20 insulating substrate. Therefore, portions corresponding to the gate insulating film 107 and a-Si film 106 below the gate electrode 108 in a thin film transistor structure are generally removed in case of a gate-line structure excluding an a-Si island.

25 However, when using the above 4PEP structure in order to reduce the number of steps, a structure similar to an a-Si island is also formed on a gate line because etching and forming a three-layer film through a patterning
30 process once. That is, the a-Si film 106 and gate insulating film 107 unnecessary for the structure cannot

be removed from a gate line exceeding an a-Si island and thereby, the films 106 and 107 are directly formed.

5 Figure 8 is a top view of a thin film transistor under the above state. A TFT necessary as a liquid-crystal display panel is an a-Si island 111 formed on a gate electrode 108 serving as a protruded portion of a gate line 109. However, another TFT is present on the gate line 109 other than the a-Si island 111 due to the above
10 4PEP structure. Therefore, a leak current shown by arrows in Figure 8 are generated from adjacent other data lines 110, adjacent other drain electrodes 104 or the like, and flows into a source electrode 105 and thereby, an extra current flows through a display electrode 112.
15 As a result, no sufficient potential is written in a pixel due to an extra current (crosstalk) and this insufficient write causes extreme deterioration of a display image.

20 The present invention is made to solve the above technical problems and its object is to reduce the number of necessary steps in a thin-film-transistor manufacturing process and prevent an abnormal potential from occurring due to a leak current from other data
25 lines.

It is another object of the present invention to provide a thin film transistor capable of preventing flickering or sticking due to the change of capacities C_{gs} between a
30 gate and a source even if a pattern is shifted between a gate line and a signal line.

Summary of the Invention

5 To solve the above problems, a thin film transistor of
the present invention is mounted on a predetermined
substrate and provided with a gate electrode formed into
a predetermined pattern, a semiconductor layer formed
correspondingly to the patterning of the gate electrode,
a pixel electrode interposed by the semiconductor layer,
10 and a signal electrode interposed by the semiconductor
layer by keeping a predetermined interval from the pixel
electrode. The signal electrode is formed at a position
for preventing crosstalk running from an adjacent signal
electrode to the pixel electrode through the
15 semiconductor layer.

In this case, it is also possible to pattern-form a gate
insulating film together with the semiconductor layer
correspondingly to the patterning of the gate electrode.
20 Specifically, it is preferable to constitute the
semiconductor layer and the gate insulating film so that
they are formed in accordance with almost the same
pattern as the case of the patterning of the gate
electrode.

25 Moreover, a structure of a thin film transistor of the
present invention is allowed to use not only the normal-
stagger type (top-gate-type) but also the reverse-stagger
type (bottom-gate type). In case of the reverse-stagger
30 type (bottom-gate type), a gate electrode can be provided
on a substrate and a semiconductor layer can be formed
above the gate electrode through a gate insulating film

as well as pattern-formed correspondingly to the
patterning of the gate electrode. On the other hand, in
case of the normal-stagger type (top-gate type), a
semiconductor layer can be formed on a layer lower than a
gate insulating film formed on the lower layer of a gate
electrode. Application to the normal-stagger type (top-
gate type) is particularly superior because the number of
photomask steps can be easily reduced.

Moreover, by disposing a signal electrode at a position
for preventing crosstalk running from an adjacent signal
electrode to a pixel electrode through a semiconductor
layer, it is possible to prevent a leak current from
other signal line which should not flow into the pixel
electrode. More specifically, it is preferable to
dispose a signal electrode so as to isolate a gate
electrode formed on an a-Si island from a gate line.

Furthermore, a thin film transistor of the present
invention has a source electrode provided on a
predetermined substrate, a drain electrode disposed by
keeping a predetermined interval from the source
electrode, a semiconductor layer disposed so as to
contact the source electrode and drain electrode and
connect the both electrodes, a gate insulating film for
covering the semiconductor layer, and a gate electrode
disposed so as to contact the gate insulating film. The
gate electrode is provided with a protruded portion
almost orthogonal to the source and drain electrodes so
as to be patterned, the semiconductor layer and gate
insulating film are pattern-formed in accordance with the
patterning of the gate electrode, and the drain electrode

is disposed at a position nearby the root of the protruded portion of the gate electrode for the source electrode.

5 In this case, when the semiconductor layer and gate insulating film are formed in the patterning step same as the case of the gate electrode, it is possible to prevent an extra current from running from an adjacent signal line (data line) into the source electrode through a gate
10 line. Therefore, this is superior in that a display image can be prevented from deteriorating.

Moreover, the source electrode and the drain electrode are preferable in that it is possible to prevent inflow
15 of crosstalk and it is possible to provide a thin film transistor free from fluctuation of stray capacitance even if a pattern shift occurs between a gate line and a signal line because the electrodes are arranged at a predetermined line width and in parallel with each other.

20 Furthermore, a liquid-crystal display panel of the present invention is a liquid-crystal display channel having a pixel electrode and a thin-film-transistor-channel structure for applying a voltage to the pixel
25 electrode and provided with a gate line for forming a gate electrode in the thin-film-transistor-channel structure, a signal line to be connected to a signal electrode in the thin-film-transistor-channel structure, and a semiconductor layer to be patterned under a state
30 along the gate line exceeding the thin-film-transistor-channel structure, in which the signal electrode is configured so as to prevent a current incoming from an

adjacent signal line for applying a voltage to the pixel electrode and a pixel electrode adjacent to the former pixel electrode through the semiconductor layer.

5 In this case, because the semiconductor layer remains on the gate line and has a parasitic thin film transistor between the adjacent signal line and the thin-film-transistor-channel structure, a large operation/working effect is obtained in that crosstalk from an adjacent
10 pixel electrode can be effectively prevented when etching a semiconductor layer by using gate-line resist or a gate-line plating pattern as a mask in a panel structure directly using a gate electrode as a gate wiring.

15 Moreover, a liquid-crystal display panel of the present invention is applied to not only a top-gate-type thin-film-transistor structure but also a bottom-gate-type thin-film-transistor structure. In case of the bottom-gate type, this gate electrode is formed on a substrate and the semiconductor layer is formed on a layer upper
20 than a gate insulating film formed on the upper layer of the gate electrode. In case of the top-gate type, the semiconductor layer of it is formed on a layer lower than a gate insulating film formed on the lower layer of a
25 gate electrode.

Furthermore, a thin-film-transistor manufacturing method of the present invention comprises the opaque film step of forming an opaque film having a predetermined shape on
30 a substrate; the insulating film step of forming an insulating film on the substrate so as to cover the opaque film; the source-and drain-electrode forming step

of forming a source electrode and a drain electrode made
of metallic films having a predetermined line width and
length and separated from each other by a predetermined
interval; the semiconductor-and-insulating-film-layer
5 forming step of forming a semiconductor layer and a gate
insulating film layer in order on the insulating film
above the source and drain electrodes, the gate-electrode
forming step of forming a metallic film for a gate
electrode on the gate insulating film layer; and the
10 pattern forming step of patterning the semiconductor
layer, gate insulating film layer, and metallic film for
a gate electrode and thereby, forming a protruded TFT
portion having a thin-film-transistor-channel structure
and forming a semiconductor layer and a gate insulating
15 film layer at a position of a gate electrode exceeding
the protruded TFT portion; in which the source-and-drain-
electrode forming step forms at least either of a source
electrode and a drain electrode serving as a signal
electrode so as to cross the protruded TFT portion formed
20 in the pattern forming step.

Furthermore, in the thin-film-transistor manufacturing
method, the pattern forming step pattern-forms a
semiconductor layer, a gate insulating layer, and a
25 metallic film for a gate electrode in the same patterning
step. In other words, a pattern forming step of the
present invention pattern-forms a semiconductor layer, a
gate insulating film layer, and a metallic film for a
gate electrode in almost the same shape. This feature is
30 superior in that the number of necessary steps can be
reduced in a thin-film-transistor manufacturing process

capable of preventing an abnormal potential from being generated due to a leak current from other data lines.

Brief Description of the Drawings

5 Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

10 Figure 1 is a top view showing the thin-film-transistor structure of this embodiment;

Figure 2 is a sectional view of AA' in Figure 1;

15 Figure 3 is a graph showing a driving waveform of a conventional TFT structure;

Figure 4 is a graph showing a driving waveform of the TFT structure of this embodiment;

20 Figures 5(a) to 5(d) are illustrations showing TFT manufacturing steps of this embodiment;

Figures 6(a) and 6(b) are top views showing a TFT structure when an alignment shift occurs;

25 Figure 7 is an illustration showing a typical structure of a conventional thin film transistor; and

30 Figure 8 is a top view for explaining a thin-film-transistor structure not constituting the present invention.

Detailed Description of the Preferred
Embodiments of the Invention

5 The present invention is described below in accordance
with the embodiment shown in the accompanying drawings.

Figure 1 is a top view showing the thin film transistor
structure of this embodiment and Figure 2 is a sectional
10 view of AA' in Figure 1. As shown in Figure 2, the thin
film transistor of this embodiment has an opaque film
(light shield) made of a Mo alloy such as Mo and MoCr on
an insulting substrate 21 made of non-alkali glass,
quartz or the like, and an insulting film 23 serving as
15 an under-coat layer made of silicon oxide SiO_x, silicon
nitride SiN_x or the like so as to cover the upper portion
of the opaque film 22. Moreover, a pixel electrode
(display electrode) 24 made of indium-tin oxide (ITO)
serving as a transparent conductive film is formed on the
20 insulating film 23 and a source electrode 25 and a drain
electrode 26 which are formed integrally with the pixel
electrode 24 and configured by superimposing a metallic
film made of a molybdenum-tungsten (Mo-W) alloy using Mo,
Ti, Ta, Cr, Nb, W, Ag or the like on the upper layer of
25 an ITO film are pattern-formed on the insulating film 23.

Furthermore, an a-Si film 27 for forming a semiconductor
layer is formed on the upper layers of the pattern-formed
source electrode 25 and drain electrode 26 and a first
30 silicon-nitride film (first SiN_x film) 28 serving as a
gate insulating film and a silicon-nitride film (second
SiN_x film) 29 which is a gate insulating film serving as

a TFT-channel passivation film are formed on the upper layer of the film 27. Furthermore, a gate electrode 30 made of a metal such as Cr or Al is formed on the upper layers of these gate insulating films.

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Furthermore, as shown in Figure 1, the source electrode 25 and the drain electrode 26 are arranged at a predetermined line width so that the electrodes 25 and 26 are separated from each other by a predetermined interval almost parallel with each other. The drain electrode 26 is pattern-formed integrally with a signal line (data line) 32 and the source electrode 25 is formed so as to contact the pixel electrode 24. Furthermore, the gate electrode 30 is configured of a portion protruded from the gate line 31 and directly used as a gate wiring. In case of this embodiment, the so-called a-Si island of a thin film transistor (TFT) is formed by arranging the source electrode 25 and drain electrode 26 so as to be almost orthogonal to the gate electrode 30 serving as a portion protruded from the gate line 31. As shown in Figure 1, the drain electrode 26 is orthogonal to the gate electrode 30 at a position closer to the gate line 31 than the source electrode 25 and is configured so as to be able to separate the gate electrode 30 for forming an a-Si island from the gate line 31. Moreover, symbols 32b and 32c denote adjacent data lines.

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In this case, the thin film transistor of this embodiment simultaneously etches the a-Si film 27, first SiNx film 28 and second SiNx film 29 respectively serving as a gate insulating film by using the pattern of the gate electrode 30 as a mask. As a result, as shown in Figure

2, the a-Si film 27, first SiNx film 28 and second SiNx film 29 are left at all lower portions of the gate line 31 and an unnecessary semiconductor layer is left below the gate line 31 other than an a-Si island.

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Figure 3 shows a driving waveform under a conventional state (for example, the above-described state in Figure 8) in which a drain electrode is not present at a position for separating the gate electrode 30 for forming an a-Si island from the gate line 31 under a state in which a semiconductor layer is left below the gate line 31. Figure 4 shows a state in which the drain electrode 26 is present at a position for separating the gate electrode 30 for forming an a-Si island from the gate line 31 under a state in which a semiconductor layer is left below the gate line 31.

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In Figures 3 and 4, y-axis denotes potential (Volt), x-axis denotes time (msec), a broken line denotes gate-line driving waveform 41, a two-dot chain line denotes data-line waveform 42, and symbols 43 and 44 respectively denote a pixel waveform. Moreover, in Figures 3 and 4, gate-on time is exaggeratedly lengthened so as to be easily understood.

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In this case, because an electric charge is written in a pixel whenever a gate is turned on, it is preferable that the potential of a pixel follows the potential of the data line shown by the data-line waveform 42. In Figure 3, however, it can be understood that the pixel waveform 43 is weakened by a value of potential V1, V2, or V3. This is because a semiconductor layer remains on the

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whole lower portion of the gate line 31 and thereby, a leak current is generated from an adjacent data line while a gate is turned on. That is, because a semiconductor layer is present between an adjacent data line and TFT and a parasitic TFT is present, a current unnecessary or undesired to drive a TFT liquid-crystal display unit is generated due to switching of a gate electrode, and thereby the pixel waveform is weakened.

Moreover, when the source electrode 25 and drain electrode 26 are arranged as shown in Figure 1, an extra current (crosstalk) from adjacent data lines 32b and 32c does not reach the source electrode 25 due to the presence of the drain electrode 26 though the current tends to flow into protrusions of the data lines. As a result, as shown in Figure 4, it is possible to keep a state in which normal electric charges are written as the pixel waveform 44. That is, even under the normal state in which a potential difference occurs between the data line 32 and the adjacent data line 32b or 32c because phases are reversed, it is possible to write a sufficient potential in a pixel without being influenced by the crosstalk written from other data line and prevent extreme deterioration of a display image due to insufficient write.

Though the above description is made by taking a normal-stagger-type (top-gate-type) thin film transistor structure as an example, the present invention can be also applied to the reverse-stagger-type (bottom-gate type) and the same operation/working effect can be obtained.

Then, a manufacturing process for fabricating the thin film transistor (TFT) of this embodiment is described below by taking a top-gate-type TFT as an example and referring to Figures 5(a) to 5(d). As shown in Figure 5(a), an opaque film (light shield) 22 is formed by first cleaning an insulating substrate 21 such as a glass substrate by means of mechanical cleaning such as brushing (scrubbing) or chemical cleaning using an acid or organic solvent and then forming a Mo alloy for shielding light at a predetermined film thickness by means of magnetron sputtering, and using photolithography for performing photo-etching by using photoresist as a mask.

Then, as shown in Figure 5(b), an insulating film 23 made of a silicon-oxide film (SiO_x) having a large adhesion is formed as a layer insulating film in accordance with the plasma CVD method. Then, films of drain and source-electrode ITO and data-bus-line Mo alloy are continuously formed through magnetron sputtering and the data bus line and the drain and source electrodes are patterned through photolithography after forming the films to form the source electrode 25 and drain electrode 26. Moreover, a pixel-electrode ITO is formed similarly to the case of a gate electrode to form the pixel electrode 24 through patterning. In case of this embodiment, the source electrode 25 and drain electrode 26 are considered so that the electrodes are parallel with each other at a predetermined line width and a predetermined interval and almost orthogonal to the gate electrode 30 configured of a portion protruded from the gate line 31 and moreover, the electrodes 25 and 26 are patterned so that the drain

electrode 26 can be set nearby the root of the protruded portion.

Then, as shown in Figure 5(c), the a-Si film 27 serving
5 as a semiconductor material is formed through plasma CVD
and thereafter, the first SiNx film 28 and second SiNx
film 29 respectively serving as a gate insulating film
are formed in order. Moreover, an Al film for the gate
10 electrode 30 and an Al film for the gate line 31 are
formed through magnetron sputtering by omitting etching
of the films 28 and 29. In case of this embodiment, the
independent etching step after forming the a-Si film 27,
first SiNx film 28, and second SiNx film 29 is omitted.
As a result, when an Al film is formed, the a-Si film 27,
15 first SiNx film 28, and second SiNx film 29 are arranged
on the entire surface of the lower layer of the Al film
exceeding the above a-Si island.

Then, as shown in Figure 5(d), the gate electrode 30 and
20 gate line 31 are formed through photolithography. In
case of this embodiment, the a-Si film 27 first SiNx film
28, and second SiNx film 29 are simultaneously etched by
using the gate electrode 30 and gate line 31 as masks.
As a result, because these films can be continuously
25 etched through one-time lithography step, it is possible
to greatly shorten the manufacturing process. In this
case, by shortening the process, a TFT array is completed
while an unnecessary semiconductor layer remains not only
in the a-Si island region around the gate electrode 30
30 necessary as a TFT but also on the lower layer of the
gate line 31. However, because the drain electrode 26 is
patterned so as to stride the root of the gate electrode

30 in the step shown in Figure 5(b), it is possible to prevent a potential from weakening due to crosstalk from an adjacent data line.

5 As described above, according to the TFT structure and TFT manufacturing process by this embodiment, it is possible to obtain the above superior operation/working effect. Moreover, in case of this embodiment, it is possible to minimize the influence of misalignment as a
10 secondary effect.

Figures 6(a) and 6(b) are top views showing a TFT structure when the misalignment occurs, in which Figure 6(a) shows a state in which the gate electrode 30 and gate line 31 are greatly shifted to right and Figure 6(b) shows a state in which the gate electrode 30 and gate line 31 are greatly shifted to left. In case of a TFT configured through the printing/plating art, thermal compression, chemical compression, and misalignment occur
15 for patterning. Therefore, as shown in Figures 6(a) and 6(b), a shift occurs between the gate line 31 and the data line 32. The shift causes change of capacities (Cgs) between a gate and a source and thereby, causes flickering or sticking. Moreover, when the source
20 electrode 25 or drain electrode 26 is removed from the gate electrode 30, the yield is greatly lowered because no electric charge is written in the pixel electrode 24 and thereby, a panel is not driven at all. Because this embodiment is configured so that the source electrode 25 and the drain electrode 26 are almost parallel with each
25 other and almost orthogonal to a protruded portion on which the gate electrode 30 is formed, the value of Cgs
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is not changed at all even if alignment errors shown in Figure 6(a) and 6(b) occur. Therefore, it is possible to prevent a display portion from deteriorating.

5 Furthermore, even if an alignment error occurs, it is possible to prevent crosstalk from coming from an adjacent data line by the drain electrode 26 and obtain a stable display image.

10 As described above, the present invention makes it possible to reduce the number of necessary steps in a thin-film-transistor manufacturing process and effectively prevent an abnormal potential from being generated due to a leak current from other data line.

15 While the invention has been particularly shown and described with respect to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and
20 scope of the invention.